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SPACE SYSTEMS OPERATIONS

TECHNICAL REPORT

TWELFTH BIMONTHLY TECHNICAL PROGRESS REPORT DEVELOPMENT OF A LUNAR CAPSULE SUBSYSTEM

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Prepared by: Ranger Programs

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April 1962

AERONUTRONIC
A DIVISION OF Ford Motor Company
FORD ROAD / NEWPORT BEACH, CALIFORNIA

CONTENTS

ILLUSTRATIONS

A LUNAR SEISMOMETER CAPSULE SUBSYSTEM FOR RANGER

1. INTRODUCTION AND SUMMARY

Under a Jet Propulsion Laboratory (JPL) subcontract calling for the development of a complete lunar capsule subsystem, Aeronutronic Division of Ford Motor Company is supplying a lunar seismographic capsule and ancillary equipments for Ranger flights RA-3, RA-4, and RA-5. For RA-3 and RA-4 this has been accomplished on schedule and with no significant deviations from specifications.

As the Ranger spacecraft approaches the moon, the capsule is to be separated from the spacecraft and braked to allow a survivable landing which implaces a sensitive seismometer on the lunar surface. Data from the seismometer is to be relayed back to earth receiving stations for an extensive period of time after each landing. Subsystems of the lunar capsule include an altimeter for sensing the proper altitude of separation; a spin rocket motor to provide stabilization during the retrorocket braking; a retrorocket; a crushable impact limiter to absorb residual energies; and the survival package. The survival package is a sphere which is fluid floated inside the hollow, spherical impact limiter to distribute the structural loads of impact and to allow erection by moon gravity to the local vertical after the assembly comes to rest. Conventional chemical batteries supply the total input power demand. Near-constant temperature for the survival sphere equipments is provided by the use of a cryogenic insulation and a small quantity of water which cools by evaporation to the vacuum surroundings during the lunar days. The water also offers a safety feature for night operation by virtue of its latent heat of freezing.

During this reporting period a number of improvements to the RA-3 capsule configuration were designed, tested, and delivered for use on RA-4. Notable among these were changes to the retrorocket, spin rocket, and the altimeter deployment mechanism. Certain further design modifications to improve reliability and/or facilitate fabrication are contemplated prior to launching RA-5.

RA-4 was launched from AMR 23 April 1962 and impacted the dark side of the moon early on 26 April. A spacecraft control system malfunction negated any chance of operation of the lunar capsule landing package. The capsule payload transmitter operated during the flight and was used to track and establish the trajectory of the spacecraft.

2. CAPSULE DEVELOPMENT, ASSEMBLY, DELIVERY STATUS

Although some development work is currently being done in certain areas of product improvement, the majority of effort on the seismometer capsule has shifted to assembly and delivery. As a result of experience gained in assembly of the RA-3 flight equipment, it was discovered that increased emphasis in the area of quality assurance was required. Consequently, during this reporting period, considerable effort was expended to provide a more effective quality assurance program to reduce attrition and increase reliability of the product.

Drawings, assembly procedures, and acceptance test procedures have been formalized and improved. As a result, quality control documentation more effectively describes the status and configuration of all flight and test hardware. Recently released quality control instructions have carefully defined the procedures required of both cognizant project engineers and quality control engineers in the area of non-conforming material control. Results of this effort are evident from the manner in which problems are being handled and the effectiveness of corrective action being specified on all non-conforming material reports (NMR).

In addition to preliminary corrective action, a Management Review Board convenes weekly to (a) review the handling of all major discrepancies, (b) assure positive corrective action, and (c) correct system or procedural deficiencies as required. Tables I and II are the Squawk Sheet Log and Non-Conforming Material Log for April. Of the 18 NMR's evaluated to date, 10 have been closed satisfactorily and 8 remain open pending final evidence of corrective action.

Development, assembly, and delivery status of the lunar capsule subsystems are discussed by major subassemblies. The general status of each assembly is noted and any development work in process is discussed in detail.

a. Landing Sphere Assembly

Some design revisions in both the mechanics and electronics of the payload are contemplated. Also tests of the Sphere S/N 010 were completed. These items are discussed below.

(1) Payload Electronics

A review has been made of all electronic equipment in the payload with the principal objective of (a) increasing reliability, (b) improving fabrication techniques, and (c) improving and expanding tests.

TABLE I

SQUAWK SHEET LOG

Drawing No.	Serial No.	Date	Space Systems Operations: Workmanship	Space Systems Operations: Design	Space Systems Operations: "OKASIS"	Space Systems Operations: Rework	Space Systems Operations: NMR	Electronic Operations: Workmanship	Electronic Operations: Design	Electronic Operations: "OKASIS"	Electronic Operations: Rework	Electronic Operations: NMR
805234	015	4-10-62	1	2	1		2					
805371A	FP-7	4-3-62						21	2	17	5	1
805371B	FP-7	4-2-62						17	2	17	2	
805371A	FP-9	4-5-62						5	1	5	1	
805663C	FP-3	4-2-62						8	2	8		2
600114	6048	4-4-62						2		1	1	
805664B	FP-3	4-4-62						8		4	2	2
805665B	FP-3	4-4-62						6		5		1
805647C	FP-10	4-11-62						26		16	10	
801268	FP-8	4-4-62						1		1		
805378B	FP-8	4-3-62						10	1	6	[illegible]	1
805378B	FP-8	4-11-62						2		1	1	
801268	FP-8	4-4-62						1		1		
805269MC	FP-7,8,9	4-6-62						3		3		
805649D	FP-3	4-4-62						12	1	9	3	1
805378B	FP-7	4-6-62						25	2	14	12	1
805680D	107	4-3-62						38	1	29	7	3
800120-11	FP-103,104	4-5-62	6	2		3	5					
805340	015	4-10-62						23		13	10	
801000E	105	4-6-62	11	9	3	9	8					
		TOTAL	18	13	4	12	15	208	12	150	58	12
		% OF TOTAL	58%	42%	13%	39%	48%	95%	5%	68%	26%	6%

TABLE II

NONCONFORMING MATERIAL LOG

Drawing No.	NMR No.	Date	Corrective Action Responsibility	Remarks
805378	18243	4-6-62	None	See NMR 18208
805649	18212	4-5-62	None	See NMR 18213
SCM157-HP015A2	18214	4-9-62	Receiving Inspection	Supplier Control notified by P. Lopatin
805378	18235	4-5-62	Project	MSG 002 11 April 62 (TWX 8353)
805377	18200	4-2-62	Design	Proposed to JPL 4-5-62
805378	18239	4-5-62	Test Equipment Project	Open Open
805378	18208	4-3-62	Design	Open
805378	18236	4-5-62	Test Plan Revision	In process
800120	18238	4-5-62	Drawing Change	In process
805663 C	18213	4-5-62	EO Required	In process
805680 D	18209	4-4-62	Workmanship	Open
801000 E	18215	4-10-62	Test Plan Revision	In process
801000 E	18247	4-11-62	Vendor or design	In process
805665 D	18210	4-4-62	Design	Corrective action taken
805670	18222	4-11-62	Accomplished	Terminal Inst'l to Vendor
805680 C	19702	4-17-62	EO Design	Test Failure Report Req'd
6U0114D	19704	4-19-62	Design	New Source Required
6U0252	19705	4-19-62		

Design modifications are planned for the seismometer amplifier and the timer and squib block to provide a more reliable system. Cabling will be modified to facilitate assembly and increase reliability. The transmitter will be modified to simplify fabrication and tune-up. Also, changes in the transmitter output cavity will provide higher output power and reduce spurious output radiation.

Test plans for Sphere S/N 010 were outlined in the Eleventh Bimonthly Progress Report. The test program for the Sphere S/N 010 lunar sphere was completed on 23 April 1962. Some effort remains in post analysis and the final test report. The basic test objectives were accomplished, although deviations from the detail test plan occurred.

The lunar capsule performance was evaluated under simulated launch, lunar impact and post-lunar impact. The effect of environmental testing and incident radiation at 960.05 mc on the transmitter RF spectrum was determined.

(a) RF Tests

RF tests were performed in a quiet box to measure the combined carrier and sideband power and index of modulation and to provide a spectrum analysis. These tests were repeated after flight vibration and lunar impact simulation. The transmitter operation was unaffected by these environments. The original RF spectrum was definitely affected by incident jamming radiation at 960.06 Mc but not in a predictable or repeatable manner. Just prior to the vacuum thermal test, the transmitter failed; preliminary analysis determined that transistor Q-3, the input driver to the varactor multiplier stages, had failed.

(b) Vibration Test

Sphere S/N 010 was vibrated to proof-test levels in three axes with both sine and noise inputs. No failures or malfunctions occurred during this test. X-ray examination before and after vibration showed no motion of the inner sphere relative to the limiter.

(c) Impact Test

A simulated lunar impact test was conducted on the Aeronutronic Hyge Machine on 23 March, 1962. The timer did not start as a result of the pre-impact acceleration, and none of the timed sequences occurred. It has been concluded that the 25-g switch did not close for a sufficient duration during the 50 MS acceleration phase to actuate the squib switches. The caging pin was not withdrawn prior to impact and was broken due to high shear forces at impact.

(d) Vacuum Thermal Tests

Subsequent to impact testing, the capsule was instrumented for external activation and monitoring of post-impact events in a vacuum thermal environment. The closure of the 25-g switch was simulated by activation of the squib switches which initiated the timer. Events of uncaging, penetrator firing, and power input to the seismo motor were normal. There was no indication of a seismo motor malfunction.

The transmitter was removed and replaced with a resistive thermal load. The sphere was reinstrumented for a thermal test in the Aeronutronic research facility vacuum chamber. The thermal test proceeded with a hot cycle (200°F) from 11 to 13 April, and a cold cycle, -320°F. The transmitter was then started and the test was concluded on 23 April with a temperature of -61°F inside the sphere. The battery voltage fell rapidly at -30°F, at which time it had operated 760 hours.

Photos in Figures 1 and 2 show Sphere S/N 010 vibration test and vacuum thermal facility.

(2) Payload Mechanics

Several tests were performed on an RA-3-type insulation to determine the decrease in thermal resistance that can be expected from impact and penetration. A comparison of test results showed an increase of 1.3 watts steady-state heat loss when the payload was subjected to impact and penetration. An additional test was run after repairing the reflector surfaces in the area of the penetrators, and a reduction in heat loss of 0.75 watt was observed at the same test conditions.

The rubber penetrator diaphragms were then coated with vacuum deposited aluminum, and the surfaces of the insulation shell in the area of the penetrators was coated with vacuum-deposited gold. The penetrator covers were bonded on the penetrators, installed in the insulation shell, and fired using a dummy insulation. A thermal test of this configuration was performed using the original insulation with a net improvement of 0.55 watt over the original post-impact penetration test. As a result of these tests, the penetrator diaphragms and inner surfaces of the insulation shell have been coated with vacuum-deposited aluminum and gold, respectively. This modification was provided for the RA-4 flight payloads.

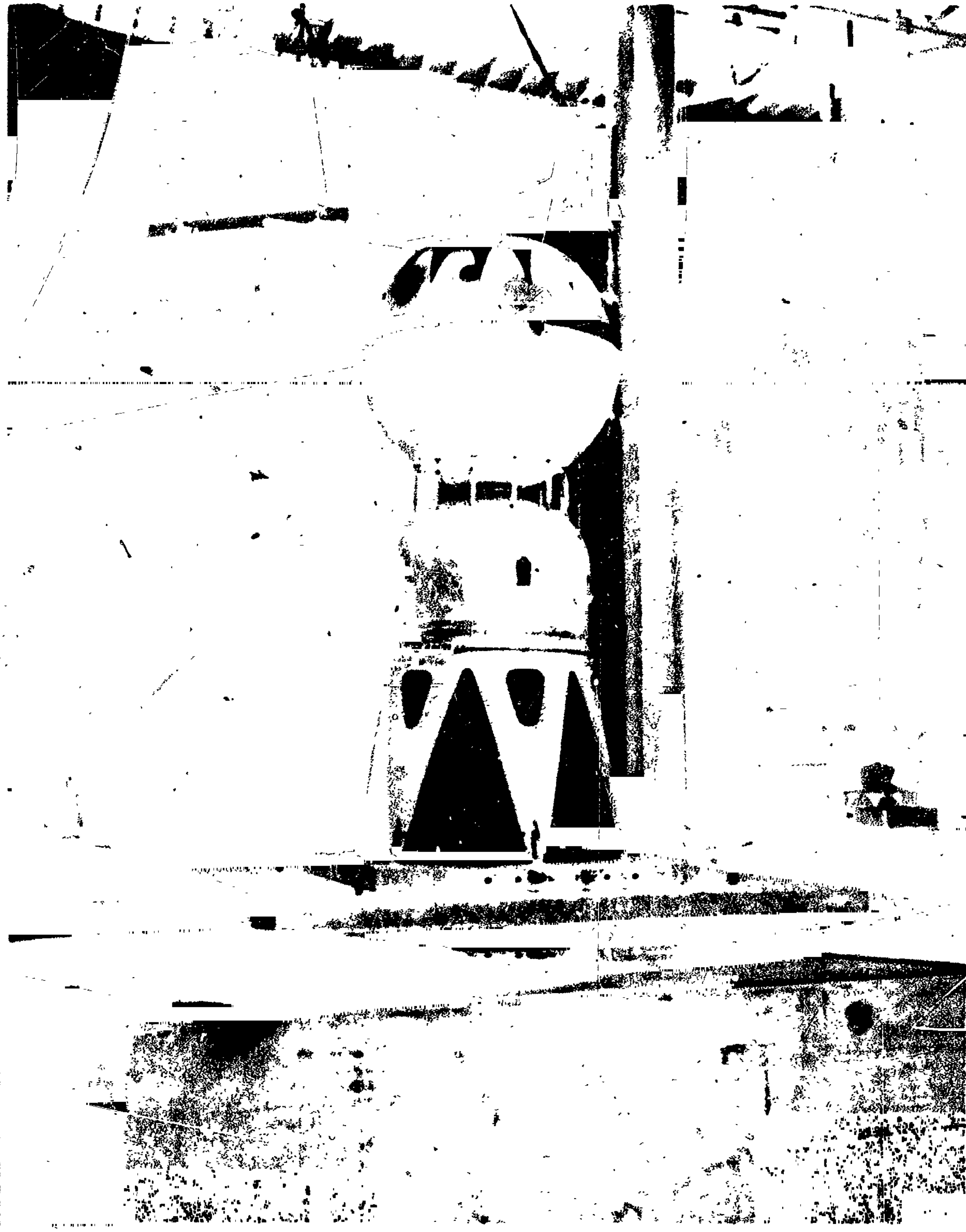
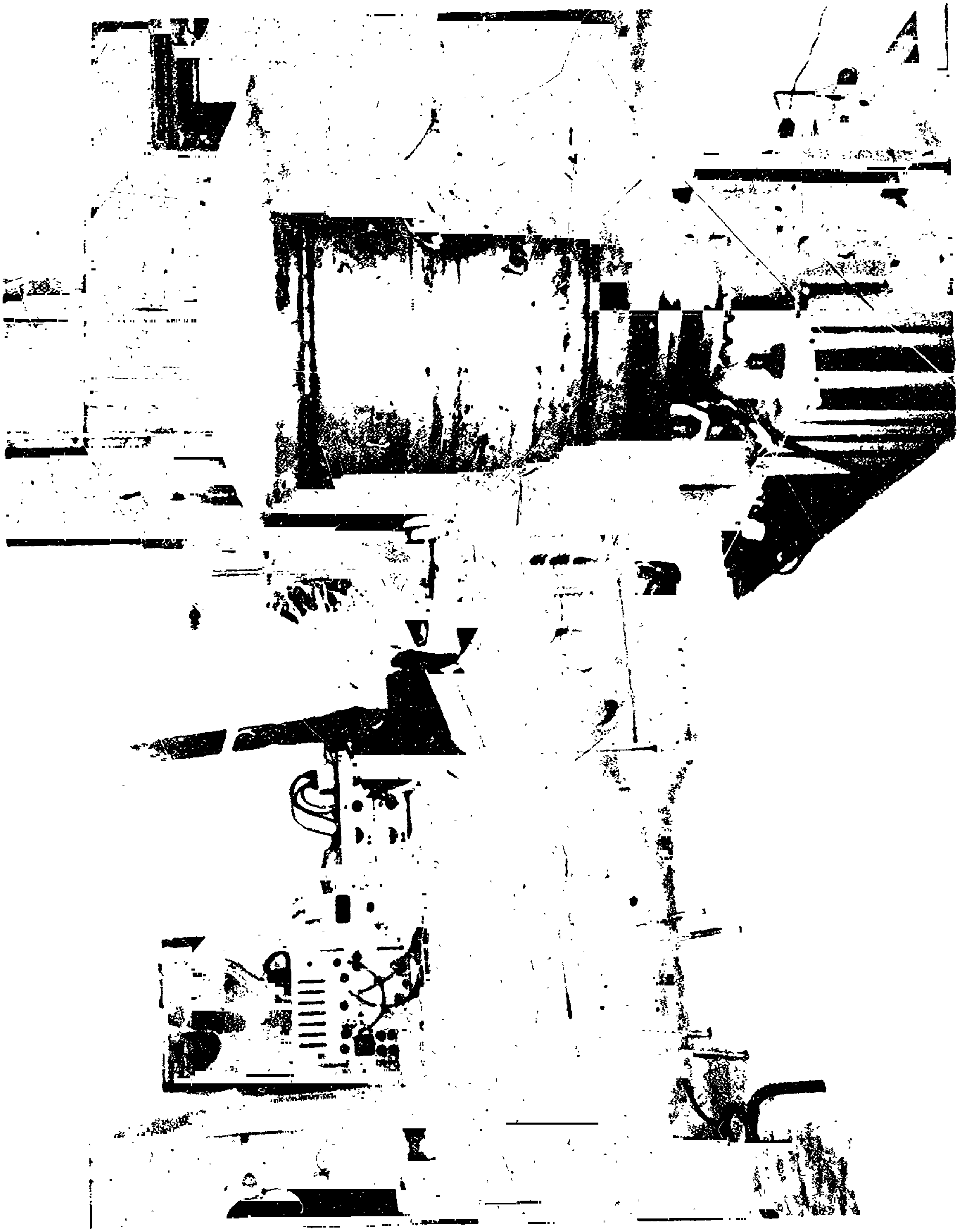


FIGURE 1. SPHERE S/N 010 VIBRATION TEST SET-UP



Two payloads (S/N 013 and 014) were provided for the April RA-4 launch. Payload S/N 015 has been carried sufficiently far in process to insure delivery as prime payload in the event launch was slipped to May. This assembly will be carried to completion and probably used as a test vehicle.

Detailed capsule assembly procedures have been revised and upgraded to a complete document, which will be released in the near future.

(3) Impact Limiter

There were no major changes made in the impact limiter design since RA-3. Permanent attachments pads for the balance weights were added in four places. Minor changes were made in the impact limiter size and the amount of paint to achieve correct final payload flight weights. The impact limiter design velocity on bottom normal impact is 192 ft/sec, side normal impact 177 ft/sec, and top normal impact 154 ft/sec.

b. Propulsion and Ordnance Devices

(1) Retrorocket

The Eleventh Bimonthly Progress Report discussed a retrorocket nozzle modification program designed to provide an external reinforcement to the expansion cone for the RA-4 flight. The reinforcement consisted of perforated stainless steel cone of 0.010-in. shim stock bonded to the exterior of the nozzle. The cone extended 8.6 inches forward of the aft face of the nozzle.

Three design proof firings were planned for the AEDC altitude facility prior to modification of the flight units. Aeronutronic and Hercules were unable to obtain test time in the AEDC Facility to support this program. It was decided that an altitude chamber with a diffuser evacuation system would be provided at the Hercules Bacchus Facility to support the tests.

On 15 February 1962, Aeronutronic issued a purchase order to Inca Engineering Corporation, Pasadena, California, for the design, construction, and installation of the test chamber. The test chamber was delivered at the Bacchus Facility 19 March 1962. The nozzle modification was installed on three motors, which were tested between 24 and 26 March.

The test chamber performed well on all tests, maintaining test chamber pressure at about one psia until thrust tail-off. The nozzle modification performed as expected and maintained the nozzle geometrical configuration throughout the firings. A water-quench system applied to the nozzle at thrust tail-off resulted in excessive damage to the nozzle cone on the first test. The water-quench system was not used on subsequent tests. Camera coverage of all tests was good and indicated successful operation of the nozzles. Figures 3, 4, and 5 show the test chamber installation and the retrorocket nozzle after firing. Nozzle damage shown occurred as a result of gas blow-back and the CO_2 quench system.

During the week of 26 March 1962, Hercules personnel, under the supervision of Aeronutronic, installed the modification on the four flight motors at AMR. The modifications weighed 6.1 $\pm$ 0.1 pounds for all motors. The modification is not expected to influence axial (thrust) performance of the motor to a significant degree. However, the tip-off torque due to nozzle deterioration will be eliminated. This will reduce the estimated cross velocity dispersion contribution from the motor from 40 ft/sec to 32.6 ft/sec.

(2) Spin Motor

The spin motor product improvement program has been completed. The design changes investigated during this program included the following:

(a) Removal of the mylar diaphragm over the grain

(b) Removal of the epoxy spacing washer at the grain end

(c) Modification of the igniter installation to eliminate potential leakage

(d) Fabrication of a special tool to size the exhaust nozzles

(e) Investigation of igniter characteristics and modification of the igniter

(f) Use of low-pressure grain in conjunction with elimination of the primary nozzle

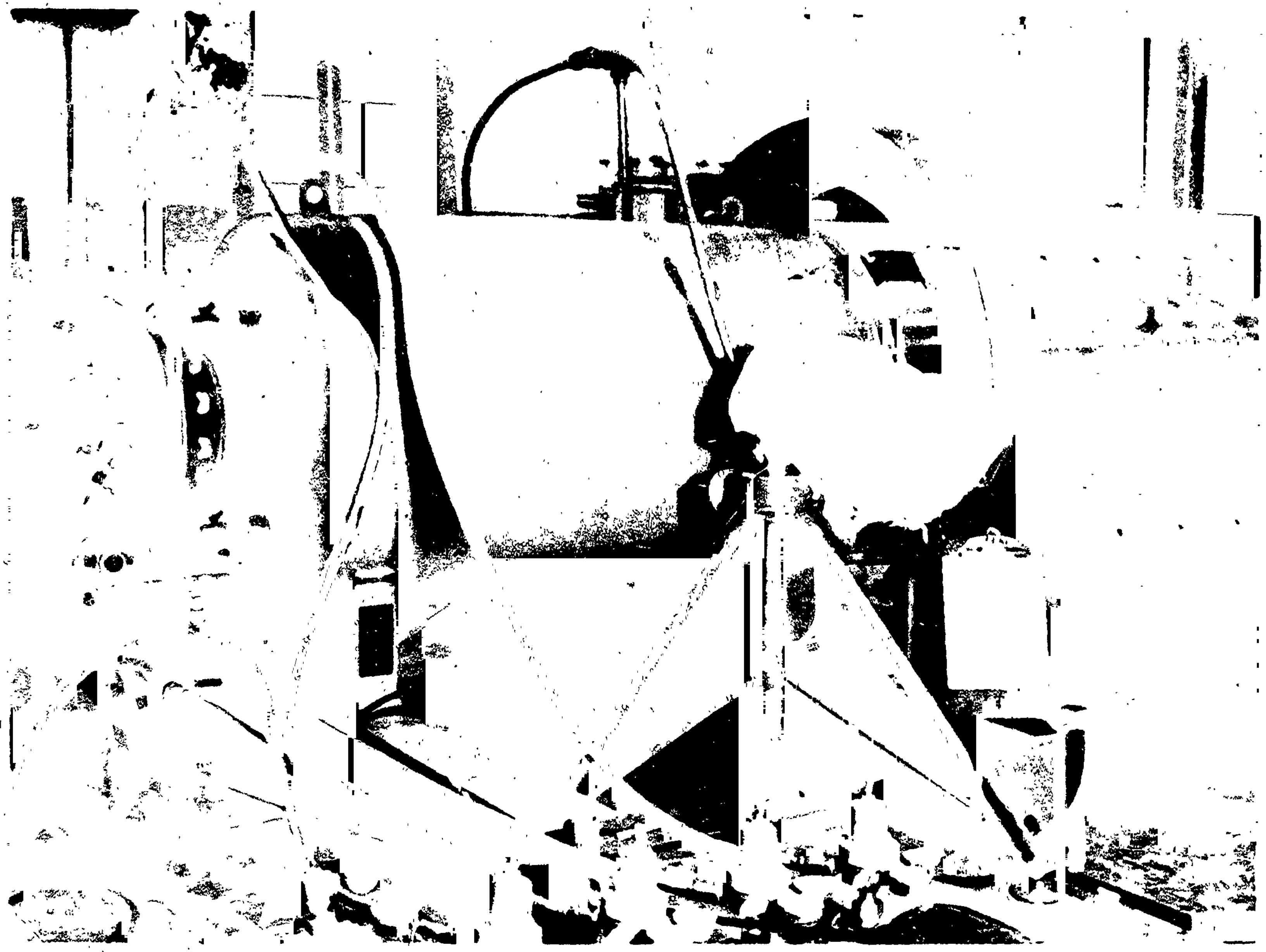


FIGURE 4. ALTITUDE TEST CHAMBER AND DIFFUSER INSTALLATION (CLOSE-UP)

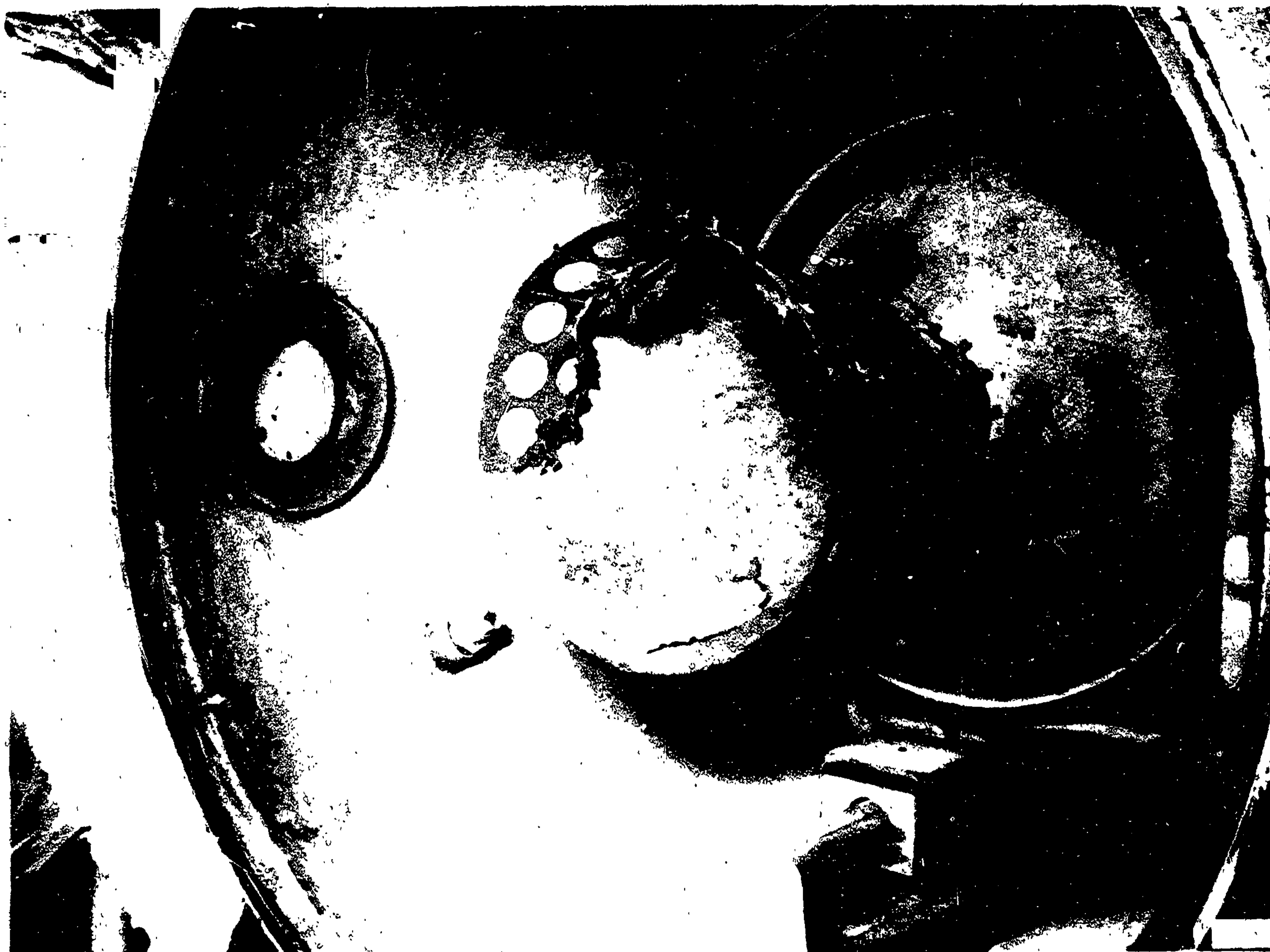


FIGURE 5. RETROROCKET MOTOR NOZZLE WITH MODIFICATION, AFTER FIRING

The product improvement program included the fabrication of 20 spin motors and additional igniters and grains for evaluation and qualification of these changes. As a result of the evaluation, all changes except the low pressure grain were incorporated. These changes appear on ADF Drawing 802100E and subs.

The spin motor qualification program was divided into three phases: (1) igniter qualification, (2) grain qualification, and (3) motor assembly qualification. The igniter and grain qualification programs have been completed. The twelve scheduled firings of the motor assembly have been made, but data analysis is not completed for the last three firings. In addition, two experimental firings of the flight configuration were conducted.

(a) Igniter and Grain Qualification

A total of 35 igniter firings and 24 grain firings have been made without indication of failure or marginal performance. These included the following:

11 - Igniter alone

9 - Igniter and grain

12 - Qualification motor assemblies

3 - Experimental motor assemblies

Igniter and grain assemblies were exposed both individually and in combination to a number of environments. In addition, three igniter-grain assemblies were exposed to all environments sequentially. The environments are as follows:

Temperature and Humidity:	70 percent relative humidity with formalin added; cycled from 0 to 120°F for three days and for fourteen days.
Ethylene Oxide:	12 hours exposure in sterilizing concentrations.
Vibration:	Sine and random in three axes to the level measured at the retro nozzle during DPT. The shake fixture incorporates a production retro nozzle.
Vacuum:	72 hours at 12 microns and 70°F. (Motors have been fired after 11 days of vacuum.)

All motors and igniters fired successfully with no indications of other than random variations in performance. There appears to be no correlation of performance variations with the various environmental exposures. The following performance parameters are significant:

Parameter	Minimum	Maximum	Average
Time to ignition peak pressure (sec)	0.024	0.040	0.032
Burning time to (sec) 5-percent tail-off	1.17	1.21	1.19
C* (ft/sec)	4060	4390	4230

(b) Motor Assembly Qualification

Of the 12 qualification firings, eight have been on the torque fixture and 4 on the gas dynamics fixture. Tip-off data are available for all but one gas dynamic fixture firing on which the symmetrical vent failed. Motors were exposed to the following nominal environments:

Temperature and Humidity:	100-percent relative humidity at 0 to 120°F for three days (nozzle closures in place).
Vibration:	Sine and random as for igniter and grain tests.
Vacuum:	72 hours at 12 microns and 70°F (nozzle closure removed).

Nine motors were exposed to these conditions. For the other three, the conditioning was modified to meet other test requirements. All motors were exposed to vacuum and were conditioned to 70°F. All firings were in a vacuum chamber at a pressure altitude of about 105,000 feet.

All test firings were successful, with no indications of leakage or incipient failure. The test data were analyzed to determine the significant system parameters, which are summarized below. These data are from the first six firings on the static torque fixture; the results of the last two firings are not yet available.

Parameter	Minimum	Maximum	RMS Average
Tip-off total angle (rad)	0.0017	0.014	0.0096
Tip-off angle orthogonal vector (rad)	0.0012	0.0099	0.00679
Equivalent cross axis velocity (fps)	11	88	60
Capsule final roll rate (rad/sec)	31.62	32.59	32.51
Burn time to 5 percent tail-off (sec)	1.0	1.19	1.153
I_{sp} (sec)	202	208	206

(c) Gas Dynamics and Spin Restraint Tests

Four tests have been conducted on the gas dynamics separation test fixture. These tests were conducted to determine the effect of the spin motor exhaust gas on capsule tip-off and to verify suitable performance of the symmetrical vent, radiation shield, and spin retraint under separation conditions.

All tests were conducted in the Douglas Aircraft Company, Long Beach, vacuum chamber. The test fixture is described on ADP Drawing 805816. Flight hardware used in the various tests included in the motor support structure (ADP Drawing 800003), the symmetrical vent (Drawing 800112), the radiation shield (Drawing 800120), and the spin restraint (Drawing 800131). All tests were conducted at a pressure of about 7 mm of Hg, equivalent to an altitude of slightly over 100,000 feet.

The test fixture used in this program is shown in Figures 6 and 7. Figure 6 shows the bus superstructure and the separation guides. The dead weight load used for calibrating primary torque of the spin motor is attached to the retro nozzle. Figure 7 show the bus rotation drive and the dead weight which simulates spin motor axial thrust. The static torque fixture on the separate mounting can be seen in the background.

The test fixture is designed to allow capsule-bus orientation through 360 degrees of rotation on the Z-axis and through 21 inches of separation along the Z-axis. The separation acceleration and velocity due to both spin motor axial thrust and exhaust gas pressures are simulated; the angular acceleration of spin-up is not. Angular orientation and

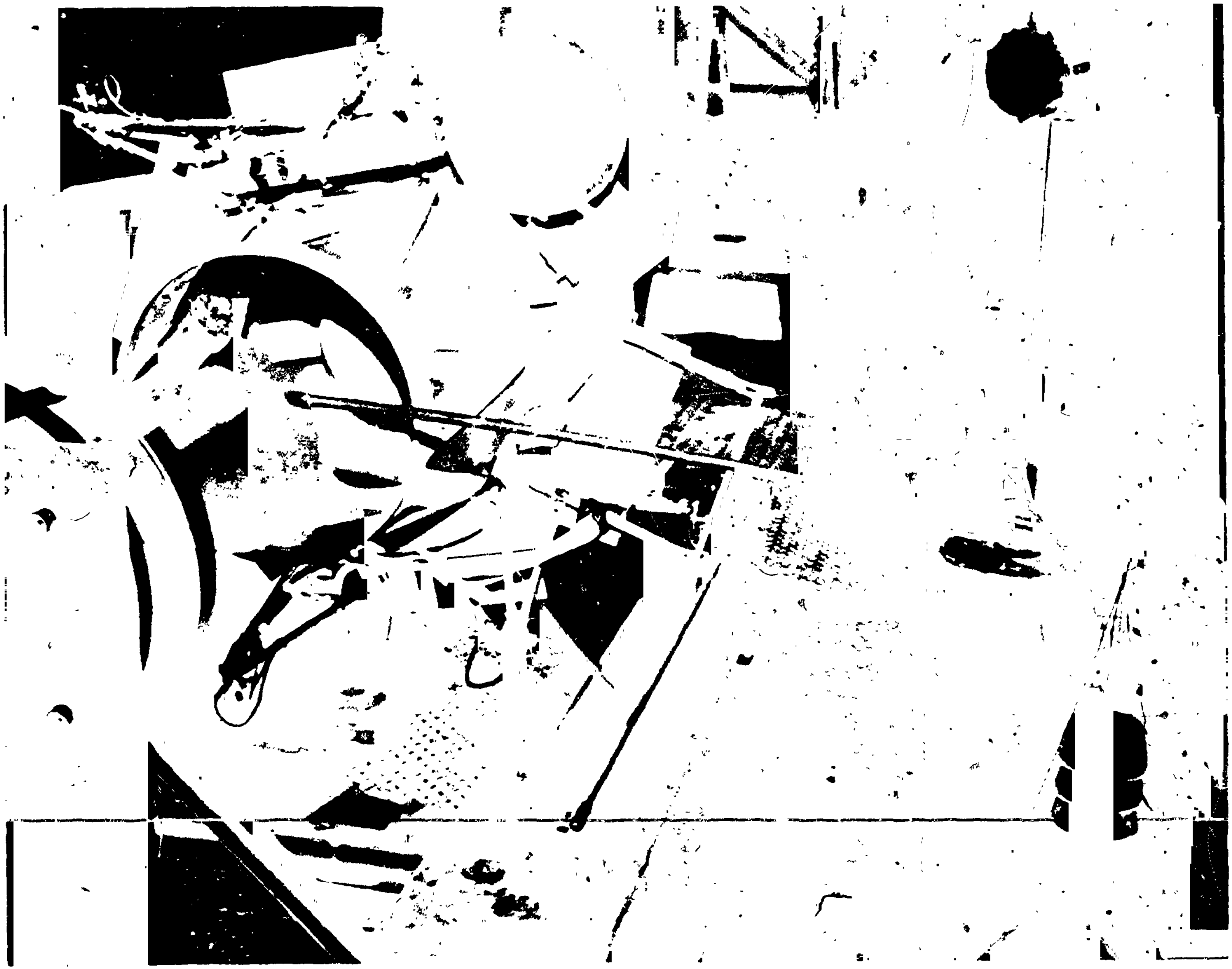


FIGURE 6 GAS DYNAMICS TEST FIXTURE

FIGURE 7. GAS DYNAMICS AND STATIC TORQUE FIXTURES

separation position are obtained by rotating or traversing the bus simulator; rotation velocity is about 0.5 radian/sec. Both the capsule and bus simulators are essentially rigid in rotation about the X and Y axes. With respect to transverse loads at the plane of the spin motor exhaust nozzles, the spring rate of the capsule simulator is about 45,000 lb/in.; the spring rate of the bus simulator for loads in the three axes is from 1700 lb/in. to 3500 lb/in., depending on load direction. The flexibility of the bus relative to the capsule presents difficulties in analyzing the spin restraint test results, as discussed later.

(d) Cold Flow Test Results

Spin motor cold flow tests were conducted on the "gas dynamic fixture", in a vacuum chamber, to determine the effects of gas dynamics on capsule performance. Data were gathered regarding the magnitude and phase of the induced spurious torque. The bus angular position is zero degrees when joint "B" is down on the test fixture, which is in line with an exhaust tube of the spin motor. Bus angle is positive for rotation clockwise (looking from capsule to bus) which is the direction of relative rotation in the actual case. For separation measurement, zero is the mated position.

The purpose of these tests was to establish a criterion for the design of a spin restraint and to determine the least favorable capsule-bus orientation for the live motor firings.

Tests were conducted with the symmetrical vent and radiation shield in position and without the symmetrical vent, but with a simulated thermal radiation shield in position. Cold flow was effected at static separation points from 0 to 21 inches, with and without rotation of the bus. Similarly, dynamic separation was performed with and without rotation. These tests were performed at altitudes of 105,000 feet (the vacuum chamber ultimate capabilities) in order to effect sonic flow at the exit of the symmetrical venting device.

The data gathered were corrected for systematic errors and the following results established:

(1) The magnitude of the torque unbalance ranges from 0 to 30 lb/in., with a mean of 1 ft/lb.

(2) The mean magnitude (considering all separation angles) of the spurious torque varies from 8 to 14 in./lb during separation from 0 to 14 inches; thereafter, the effects of gas dynamics rapidly diminish and the spurious torque assumes a value approaching the inherent motor unbalance. These results are shown in Figure 8.

(3) The mean magnitude (over the full range of 0 to 21 inches separation) varies sinusoidally as a function of separation angle with a range of 6 to 14 lb/in.; peaks occur every 120 degrees of rotation. These results are shown in Figure 9.

(4) The phase of the unbalance appears to be a uniformly distributed, random phenomenon.

It was noted that, in the presence of a <u>simulated</u> radiation shield (insensitive to gas flow), the absence of a symmetrical vent did not significantly alter the nature of the spurious torque.

(e) <u>Spin Restraint Test</u>

The spin restraint wa installed per drawing and the spring rate calibrated by dead weight. The spring rate is essentially constant in all directions and is about 340 lb/in. (Figure 10).

In mating tests with the capsule simulator, it was determined that the best installation that can reasonably be made results in a lateral offset of about 0.003 in. From previous firings it appears that this lateral displacement of the spin motor hub at approximately 1-in. separation is equivalent to 0.005 radian for less final tip-off angle. This comparison is quite conservative, since the comparative tip-off angular velocities would not apply with the restraint in place.

The support arms of the restraint are directly in the exhaust cone of the spin motor. To check the magnitude of unbalanced load that results, cold flow tests were conducted with the trestraint just disengaged. The restraint was found to deflect about 0.004 inch, equivalent to about 40 in./lb tip-off moment. This must be included in the tip-off computation.

In general, the spin restraint performed satisfactorily, showing no tendencies toward resonant vibration, excessive deflection, or binding.

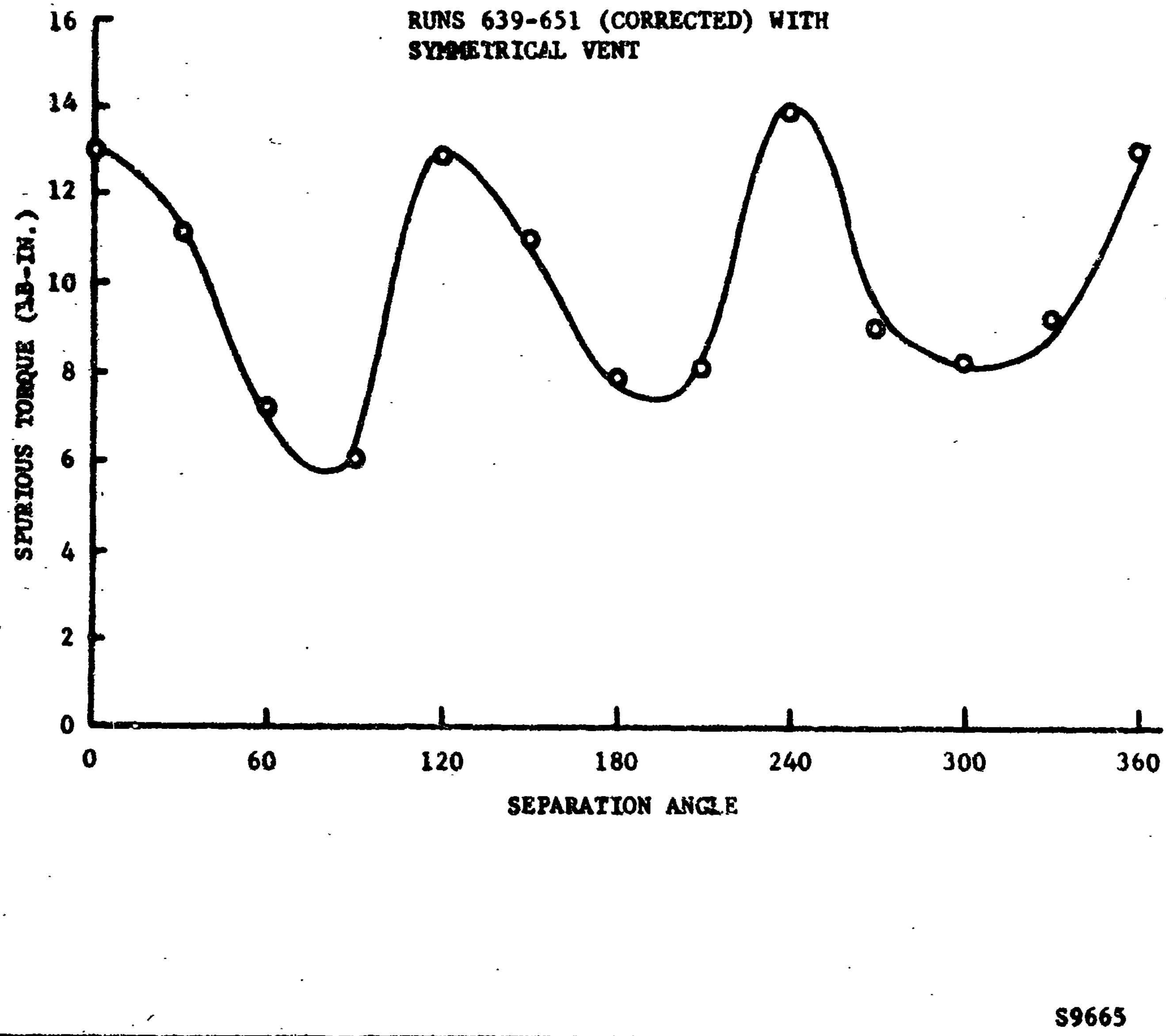


FIGURE 8. MEAN SPURIOUS TORQUE COLD FLOW GAS DYNAMIC FIXTURE

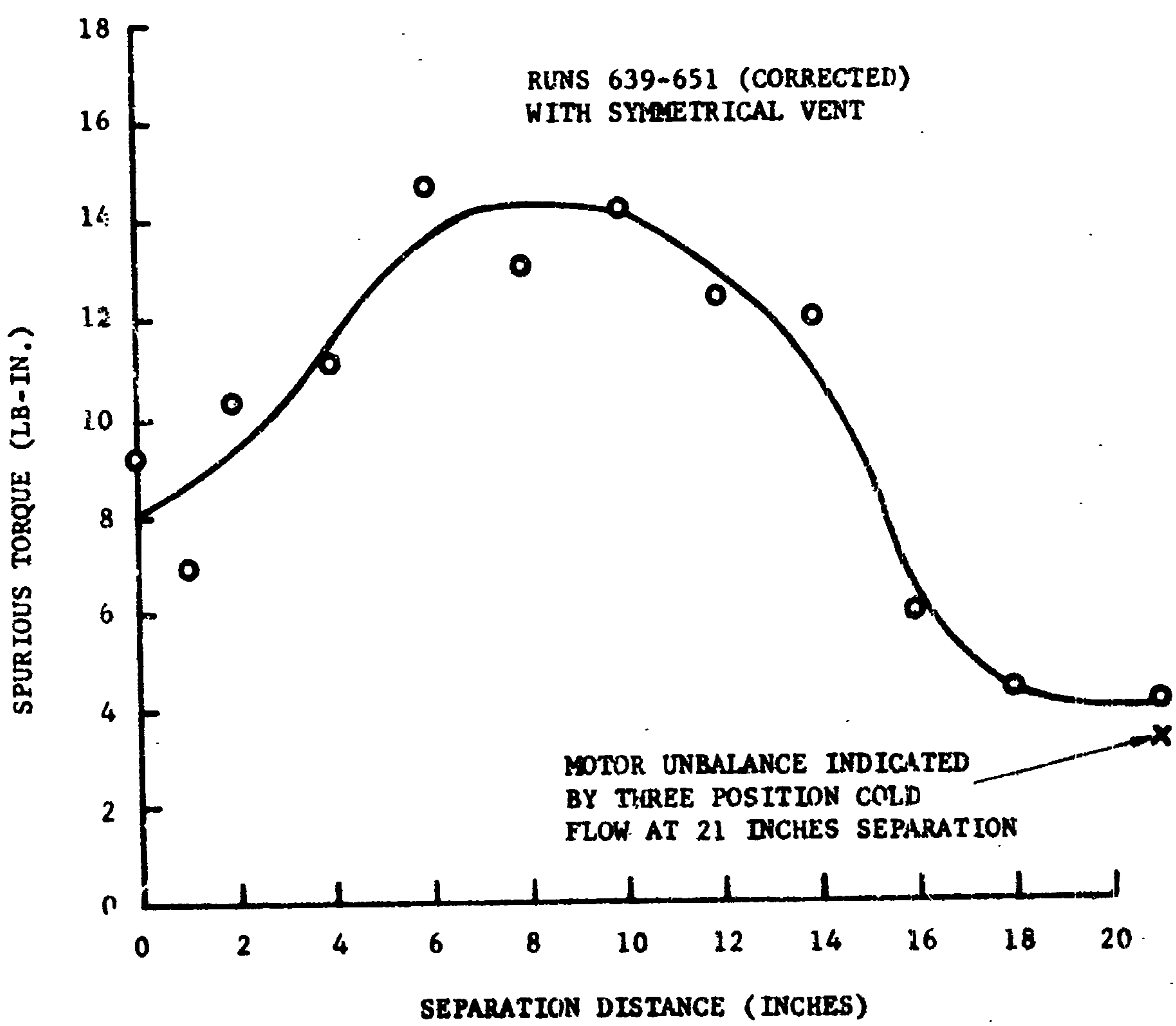


FIGURE 9. MEAN SPURIOUS TORQUE COLD FLOW GAS DYNAMIC FIXTURE

FIGURE 10. SPIN RESTRAINT DEVICE

(f) <u>Motor Firing Tests</u>

A total of four firings was made on the gas dynamic fixture. This preliminary report includes a discussion of the tip-off characteristics and other items of immediate interest. Complete analysis and discussion of various pressure and temperature data will be included in a later, more complete report. At this point it is sufficient to note that no unusual or unexpected data were observed.

<u>Run No. 248:</u> 16 March 1962

(1) Test Configuration

- Spin Motor S/N L-308
- Radiation shield 802120 A (w/o black cover)
- Symmetrical vent 800112 A (Plastic part w/o reinforcement)
- Bus angle zero degrees - did not rotate during run.
- Fired in closed position - separate at normal axial acceleration.
- Fired at pressure altitude of 103,000 ft.

(2) Instrumentation

- Channel 1; Squib current
- Channels 2 - 4; tip-off and primary torques
- Channel 5; Axial travel
- Channel 6; Bus unlatch
- Channels 7 -12; exhaust temperatures
- Channels 13-17; exhaust pressures
- 400 frame/sec motion picture

(3) Test Results

The symmetrical vent was severely damaged. It apparently buckled outward in the lower third (above the heavy section) in the area of impingement of the spin motor exhaust. The upper edge buckled in with a fluttering action and contacted the retro nozzle in at least nine places. Contact areas were spaced about 120 degrees around the nozzle, approximately in line with the spin motor nozzles, and at separation distances from 8 to 14 inches. As a result, the tip-off data were invalid. The test hardware after firing are shown in Figure 11.

The radiation shield shows only superficial heat damage.

The marks where the symmetrical vent contacted the retro nozzle can be noted. This contract caused high-frequency tip-off torque readings which, although the total impulse was small, made it impossible to use the data.

Run No. 254: 26 March 1962

(1) Test Configuration

- Spin Motor S/N L-314
- Radiation shield 302120 A (w/o black cover)
- No symmetrical vent
- Bus rotated at constant angular velocity of about 0.5 rad/sec.
- Fired in closed position with normal axial accelerations.
- Fired at pressure altitude of 102,000 ft.

(2) Instrumentation

- Same as for Run No. 248, except that an angular position trace was substituted for one of the temperature channels.

(3) Test Results

The radiation shield was severely damaged. It was completely blown away on one side except for a narrow portion in the attaching area, as shown in Figure 12. The markings on the retro nozzle show extensive

FIGURE 11. TEST OF MODIFIED HAT AND HEAT SHIELD

FIGURE 12   RADIATION SHIELD AFTER SPIN MOTOR FIRING (WITHOUT

contact by the radiation shield, which was confirmed by the motion picture of the test. Motor and tip-off data are tabulated in Table III.

Run No. 262: 7 April 1962

(1) Test Configuration

- Spin motor S/N L-304
- Radiation shield 800120 B (w/black cover)
- Symmetrical vent 800143 (w/aluminum reinforcement)
- Spin restraint 800135
- Bus angular position 180 degrees, did not rotate during run.
- Fired in a closed position, with normal axial accelerations.
- Fired at pressure altitude of 105,000 ft.

(2) Instrumentation

- Channel 1; Squib current
- Channels 2-4; Tip-off and primary torques
- Channel 5; Axial travel
- Channel 6; Bus unlatch
- Channel 7 and 8; Restraint deflection
- Channels 9-12; Exhaust temperatures
- Channels 13-17; Exhaust pressures
- 400 frame/sec motion picture

(3) Test Results

The symmetrical vent and radiation shield showed superficial damage. There were no indications of contact with the retro simulator. The test hardware after firing are shown in Figure 13.

During the first 100 millisec, there was indication of high tip-off torque ($\sim$10 ft-lb.). It was subsequently determined that this was caused by deflection of the bus simulator due to internal gas pressure. The amount of deflection was estimated from cold flow, and the corresponding tip-off moment subtracted out of the data for tip-off analysis. The results are tabulated in Table III.

TABLE III

CAPSULE TIP-OFF TEST DATA

Run No.	Configuration	Without Restraint Tip-Off Orthogonal Vector (rad)	Cross Axis Velocity (fps)	Tip-off Orthogonal Vector(rad)	Cross Axis Velocity (fps)
248	Radiation shield w/o black cover Symmetrical vent w/o reinforcement	Symmetrical Vent Failure - No Data			
254	Radiation shield w/o black cover No symmetrical vent	0.0109	97	0.0048	43
262	Radiation shield w/ black cover Symmetrical vent w/ reinforcement Spin Restraint	-	-	0.0033	29
265	Radiation shield and symmetrical vent refired from No. 262 spin restraint with contact pads removed for test	0.0040	36	0.0017	15

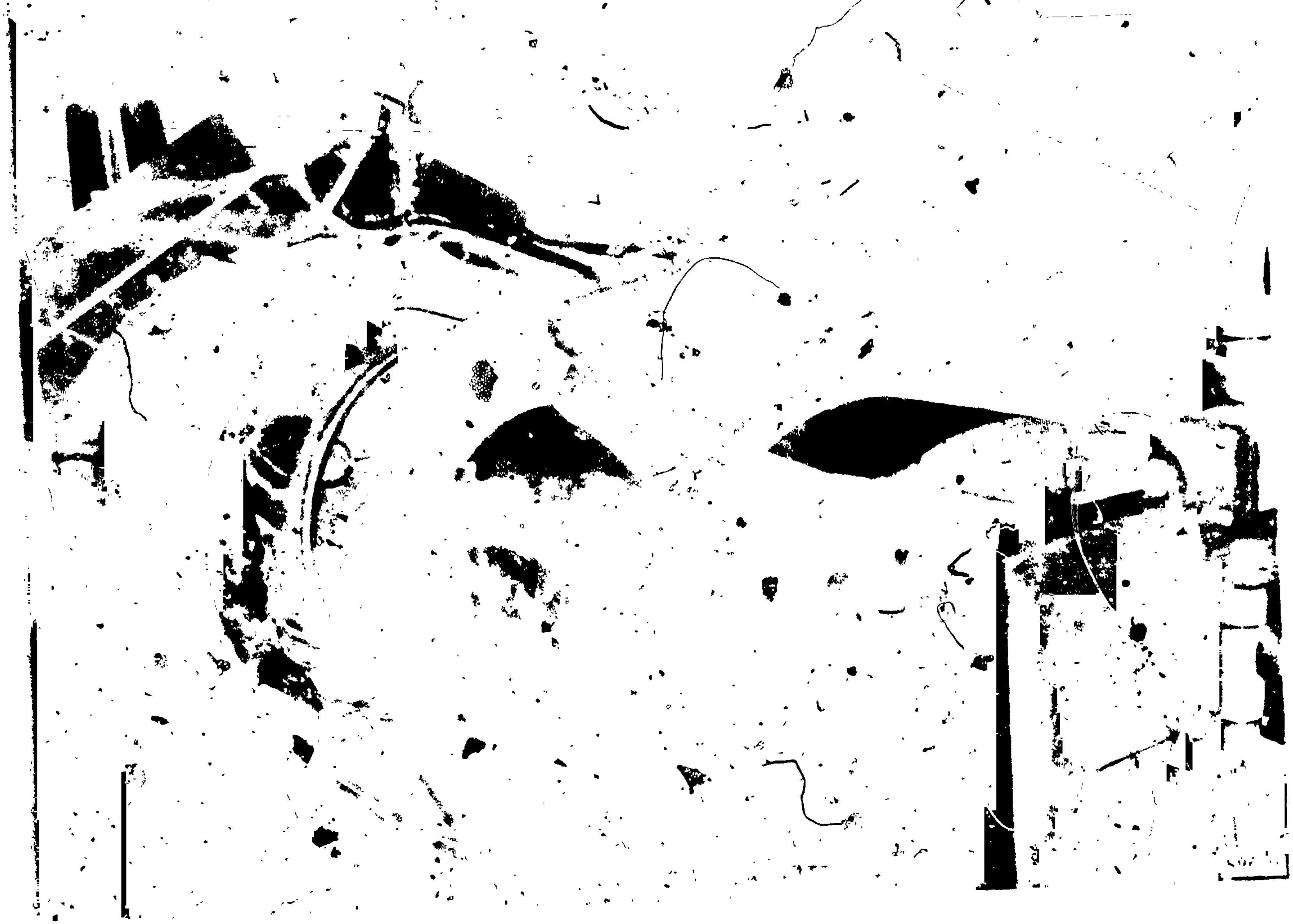


FIGURE 13. FLIGHT TYPE RADIATION SHIELD, SYMMETRICAL VENT AND SPIN RESTRAINT DEVICE, AFTER SEPARATION TEST

The spin restraint apparently performed satisfactorily. In spite of direct exhaust blast on the attaching arms and springs, it returned to zero after the firing, with the spring constant unchanged. There was heavy deposit of exhaust residue on the exposed spring leaves.

Run No. 265: 11 April 1962

(1) Test Configuration

- Spin motor S/N L-312
- Radiation shield and symmetrical vent used from previous firing (Run 262).
- Spin restraint 800135 - modified. The teflon shoes were removed from the restraint, and one lug was ground down to allow clearance for the bus deflection.
- Bus angular position 180 degrees; did not rotate during firing.
- Fired in closed position, with normal axial accelerations.
- Fired at pressure altitude of 105,000 ft.

(2) Instrumentation

- Same as for Run No. 262, except a bus vertical deflection trace was substituted for one of the pressure channels.

(3) Test Results

No change in the condition of the heat shield or symmetrical vent could be observed. Performance of the entire system appeared to be satisfactory.

With the spin restraint relieved, the tip-off torques read directly as "no restraint" torques. The tip-off load caused by the spin restraint was computed from the measured deflection of the restraint and superimposed on the recorded torques. The results were analyzed both with and without restraint and are tabulated in Table III.

c. Auxiliary Equipment

(1) Altimeter

The deployment mechanism used on the altimeter of RA-3 consisted of a "mousetrap" spring actuator and a wedge type spring latch. The mechanism was redesigned to incorporate a drive device with increased torque capability. The latches were eliminated. The new deployment mechanism replaces the crossbar on the structure between the two hinge bearings and was retrofitted into existing structures. The deployment mechanism is actuated by a heavy spring and uses a governor for speed control. The governor is of the centrifugal brake type used in telephone dials. The governor controls the deployment time to 9 $\pm$ 1/2 sec.

An altimeter structure complete with the new deployment mechanism was design proof-tested and qualified through the environmental conditions for flight. Two flight altimeters were retrofitted with the new deployment mechanism and delivered for flight on RA-4. Figure 14 shows the altimeter support structure as modified to incorporate the new drive mechanism.

(2) Radiation Shield

The basic design of the radiation shield remained unchanged since RA-3. At the request of JPL, a low reflectance exterior surface was provided, consisting of 1.2 oz Zetta black nylon spinnaker cloth. Reflectance data on this material backed up with aluminized Mylar is shown in Figure 15. A design proof article of this new assembly was heat-sterilized and a complete series of design proof tests was conducted on the assembly (including cold retraction) qualifying it for flight. Two flight assemblies were delivered in support of RA-4.

(3) Symmetric Venting Device

Hot firings of the spin motor in vacuum indicated that buckling occurs on the trailing edge of the symmetric venting device. These firings also indicated that some delamination occurs in the fiberglass laminate. An aluminum skin of 0.012 in. was provided for the outside of the device and a reinforcing ring on the inside. An assembly of the revised design was then tested in hot firings and through the vibration environment and thus qualified for flight. Figure 16 shows a photo of the improved unit. Two flight assemblies were delivered for RA-4.

FIGURE 14. MODIFIED ALTIMETER SUPPORT AND DEPLOYMENT STRUCTURE

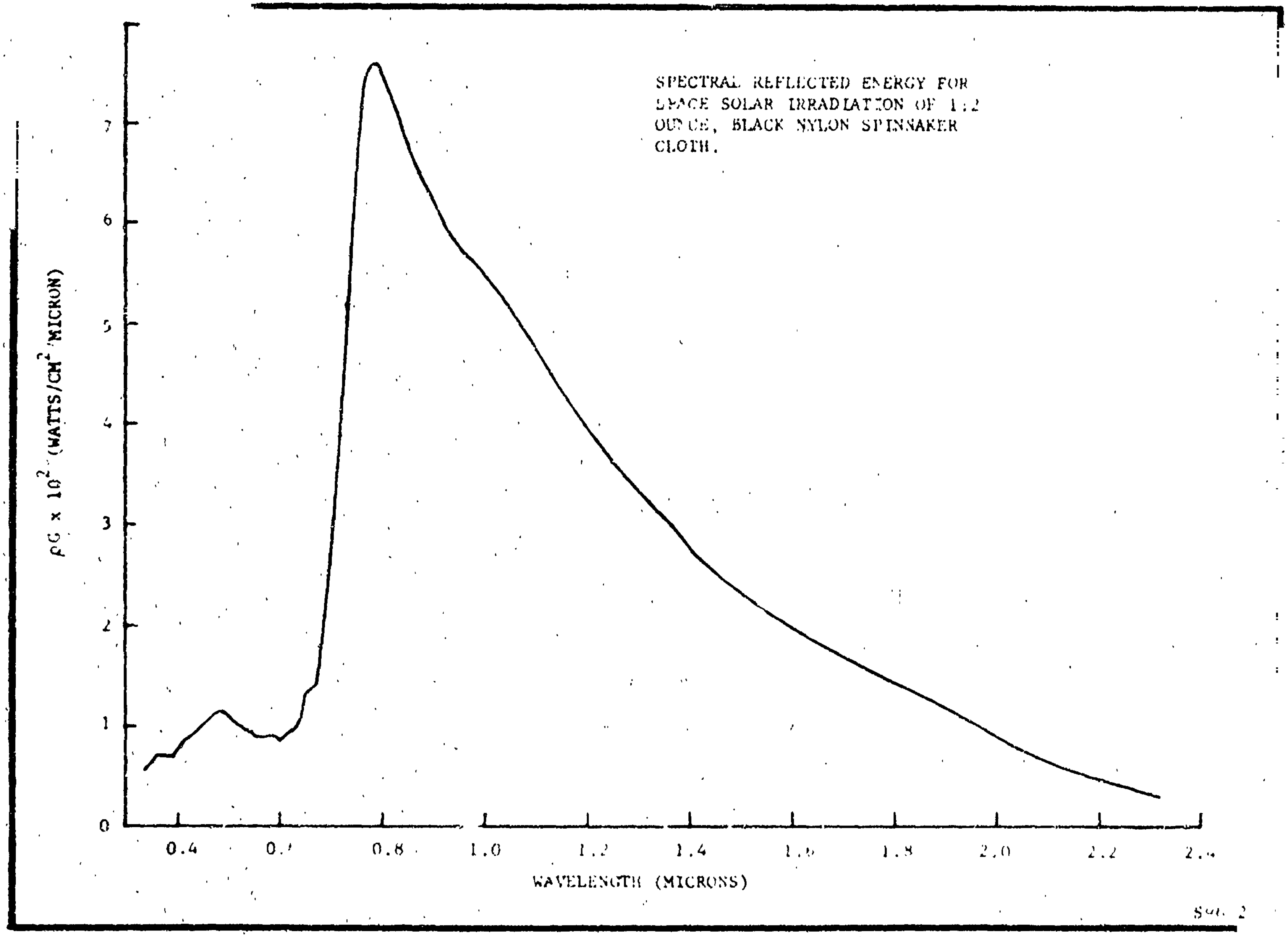


FIGURE 15. REFLECTANCE VERSUS WAVELENGTH, ZETTA BLACK NYLON

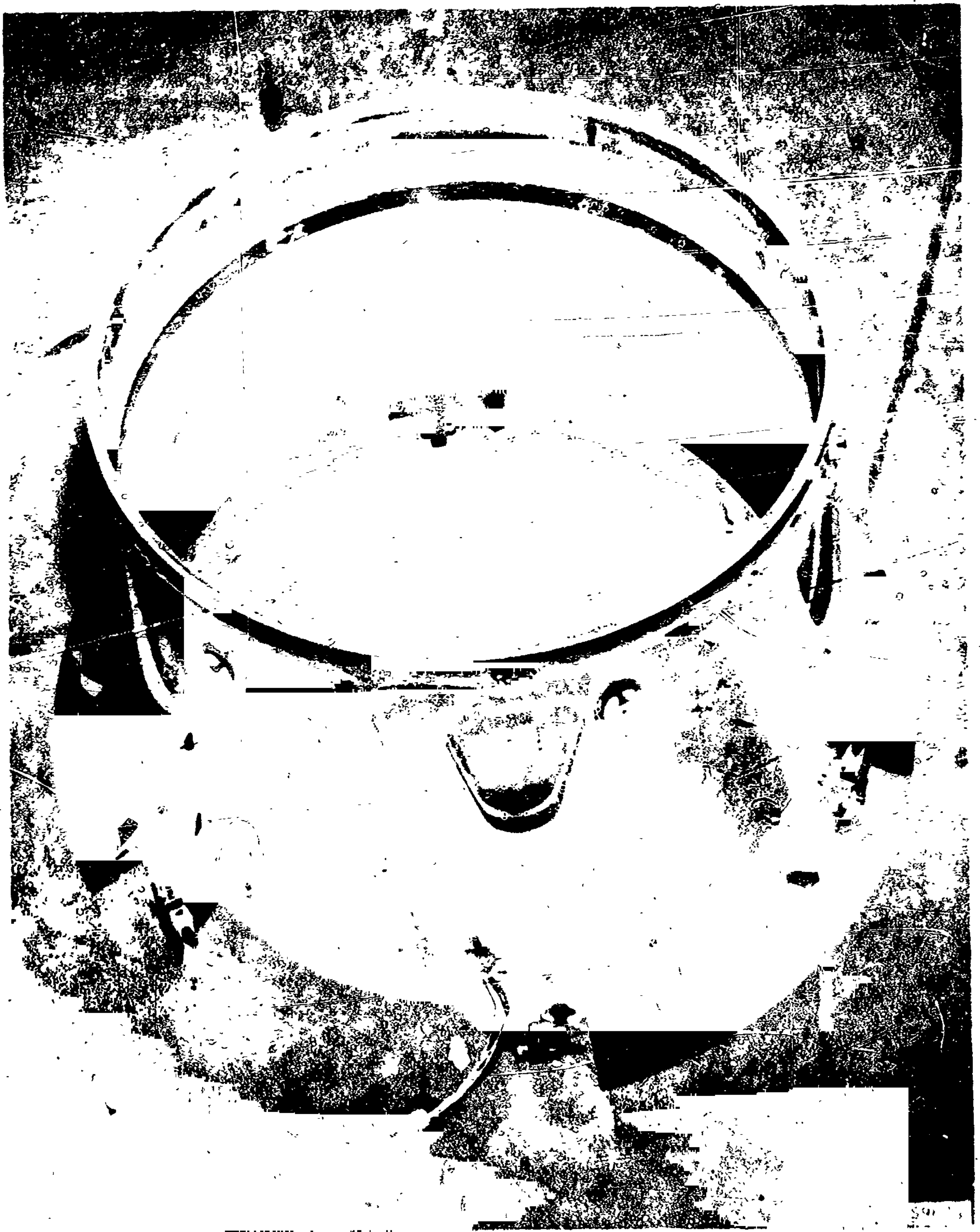


FIGURE 16. MODIFIED SYMMETRICAL VENTING DEVICE

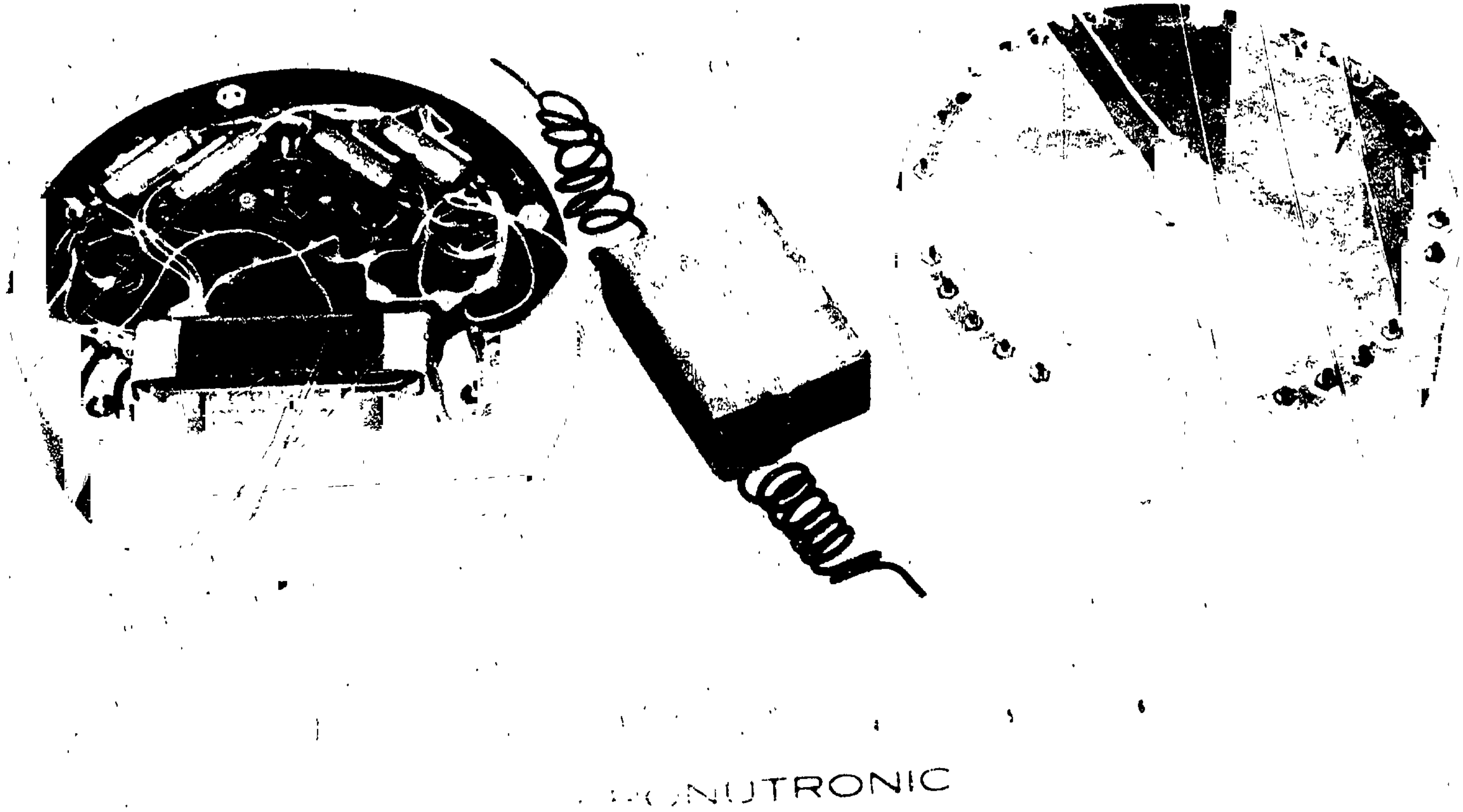


FIGURE 17. MODIFIED POWER AND SEQUENCING ASSEMBLY

(4) P&SA and External Wiring

(a) Power and Sequencing Assembly

The power and sequencing assembly, ADF Drawing No. 805378 (P&SA), consists of timing circuitry and a battery. It is packaged into a 4-1/2-inch-diameter by 2-inch-high cylinder which is installed between the retromotor and the sphere impact limiter. The functions of the P&SA are as follows:

(1) To arm the ordnance circuits at 5g acceleration during acceleration during launch.

(2) To fire the spin motor at 215 milliseconds after receipt of the altimeter fuse signal.

(3) To fire the retromotor at approximately 2 seconds after receipt of the altimeter fuse signal. This time delay is controlled by the temperature of the retromotor.

(4) To fire the landing sphere separation bolts at 12-1/2 seconds after the altimeter fuse signal.

Two design changes in the P&SA were made between fabrication of the RA-3 and RA-4 flight hardware. First, the SCR switch Q_5 of schematic No. 805396 was changed from a 2N1595 to a 2N885. The 2N885 requires less trigger current than the 2N1595 which had to be specially selected for this application. Second, the battery within the P&SA was changed from an Aeronutronic-assembled pack of Yardney PM01 cells to a sealed ESB model 199 battery. Both types of batteries passed the design proof test, but the ESB was spillproof, smaller, and had superior electrical characteristics. The P&SA was modified as shown in the accompanying photograph (Figure 17) to facilitate the installation of the ESB battery.

It is presently planned that the P&SA will be redesigned prior to RA-5 to better utilize the space made available by incorporation of the smaller battery. The squib switches and fuses will be placed in removable modules to facilitate assembly and replacement. More terminals will be provided for the connection of external wires. Provision will be made for the addition of another timer if required by a change in mission assignments.

(b) External Wiring

The terminology of external wiring is used to describe all Lunar Capsule wiring external to the survival sphere. It includes these portions shown by ADF Drawing No. 800037:

(1) The junction box and wiring on the altimeter support structure.

(2) The wiring on the retromotor support structure.

(3) The electrical contacts on the motor separation clamp.

(4) The wiring on the retromotor.

The external wiring provides the electrical connections between the JPL portion of the spacecraft, the radar altimeter, the PS&SA, and the ordnance bolt-cutters. No major design changes in external wiring were made between the fabrication of the RA-3 and RA-4 hardware. No significant difficulties were encountered during the fabrication and testing of the external wiring for RA-4.

3. FLIGHT MISSIONS

Following is a summary of the results of the two flight tests to date.

a. RA-3

The RA-3 mission was launched 26 January 1962. Booster malfunction prevented lunar impact and thus prevented operation of most of the landing capsule functions.

Telemetry records of the Jet Propulsion Laboratory indicated no signal was received confirming deployment of the radar altimeter. After studying the problem, it was concluded that the probability of altimeter deployment malfunction existed and warranted product improvement in this area. The deployment mechanism was redesigned and qualified for RA-4 as discussed in Section 2.c.

During pre-launch checkout of the RA-3 payload, it was noted that the spacecraft transponder receiver threshold was degraded by spurious radiation for Sphere No. S/N 010 transmitter. The spurious signal, at 890 Mc, was most prominent in the "shroud-on" condition and was of such a magnitude that the mission was in jeopardy. As a result of this difficulty, Sphere S/N 012 was placed on the spacecraft as prime flight item. Some degradation of the transponder threshold was noted with this sphere; however, the amount of degradation was not sufficient to jeopardize the prime objective of the mission. Tests performed on Sphere S/N subsequent to launch of RA-3 have not disclosed the cause of the spurious signal radiation from the transmitter.

In addition to the redesign of the altimeter deployment mechanism discussed above, it was decided that significant system improvements could be accomplished by product improvement work on the spin motor and the retromotor. These items are discussed under Section 2.b above.

b. RA-4

The RA-4 vehicle was launched from AMR 23 April 1962. The spacecraft impacted the dark side of the moon on 26 April 1962. A malfunction in the spacecraft control system negated any chance of operating the landing package. The capsule transmitter functioned normally and was being used to track and establish the trajectory of the spacecraft.

At this writing, a complete report of field operations in preparation for launch is not available. No significant problems were encountered during launch preparation with the exception of RF interference experienced from Sphere S/N 014 as discussed below.

The transmitter for Spheres S/N 013 and 014 were tested, at various stages of assembly, for spurious radiation at frequencies in the vicinity of 890 Mc. These tests were conducted with a standard field intensity meter and with a spectrum analyzer under conditions simulating the "shroud-on" configuration. No evidence of transmitter malfunction was disclosed during these tests; however, the ultimate sensitivity of the test equipment is inadequate to verify the presence or absence of signals that would interfere with the spacecraft transponder.

Sphere S/N 013 was tested on the PTM at JPL prior to its shipment to AMR. A small amount of interference was noted in the "shroud-on" condition; however, it was not adjudged to be detrimental to flight. Sphere S/N 014 was shipped to AMR without this additional testing at JPL. Subsequent tests of Sphere S/N 013 and 01 , in conjunction with the RA-4 spacecraft at AMR, disclosed an interference problem with Sphere S/N 014. The transponder threshold without the sphere was -139 dbm. With the sphere in place, but without the shroud, the threshold was -132 dbm. Addition of the shroud further degraded the threshold to a value of -110 dbm. The sphere was shipped to JPL for testing on the PTM to determine if "clocking" of the sphere with respect to the spacecraft could change the interference level. These tests disclosed that "clocking" of the sphere with respect to the spacecraft could change the interference level by as much as 8 db.

Sphere S/N 014 was returned to AMR for use as a back-up payload for RA-4 in the event of failure of Sphere S/N 013.

4. FUTURE PLANS

a. Product Improvement

During the period between the launching of RA-4 and the delivery of lunar capsules in mid-September, a product improvement program will be undertaken. This program will cover modification to the transmitter, redesign of the sequencing timer, redesign of the power and sequencing assembly. The purpose of the program is to improve the producibility, reliability and characteristics of the items listed.

In the case of the transmitter, it is believed that the changes envisaged will reduce RF interference with JPL transponder, reduce tune-up time, and improve its efficiency. Present planning is on the basis that design changes will have been incorporated and tested by mid-May, in sufficient time to meet the build-up schedule for RA-5.

The present design of the sequence timer is such that its assembly is time-consuming and difficult of getting good quality assurance of the end product. Redesign is on the basis that quality assurance of the end item can be improved and that it can in fact be assembled readily. Present plans call for a "welded unit" rather than one that is assembled by soldering. This new design will be incorporated into RA-5.

The status and future plans for the power and sequencing assembly is covered in detail under auxiliary equipment, Section 2.c of this report.

b. RA-5 Support

A "build-up" schedule has been prepared for RA-5. This schedule is based on starting build-up on or about 1 August with the delivery of landing Spheres S/N 017 and 018 to AMR on or about 15 September. Sphere S/N 019 will be delivered approximately thirty days before launch date. Also to be available in partial assembly will be Sphere S/N 016 and sufficient parts to complete the assembly should the need arise.

Four storage or surveillance retrorocket motors will be fired in the AEDC altitude facility during the last two weeks in September 1962. Conditions for these firings will be identical to those of the acceptance test rounds fired during November 1961. These tests will serve to establish what, if any, effect long-term storage has on performance and reliability of the retromotor.

Some product improvement work is planned for incorporation on RA-5, as discussed in the above report.